

GLOSSARY

3α process *See* triple alpha process.

aberration An effect that causes the apparent direction of a star (as observed from the Earth) to differ from its true direction in a way that changes systematically throughout the year. The effect arises from the combination of the finite speed of light and the movement of the Earth as it orbits the Sun, and requires that a telescope being used to observe a star must be pointed slightly away from the true direction of the star.

absolute visual magnitude A numerical measure of the intrinsic brightness of a star, equal to the apparent visual magnitude the star would have if observed from a standard distance of 10 parsecs, in the absence of interstellar absorption.

absorption A process that leads to a decrease in the intensity (of flux density) of radiation as it passes through a medium (e.g. the interstellar medium).

absorption lines Narrow wavelength or frequency ranges in a spectrum where the spectral flux density is less than at adjacent wavelengths (or frequencies).

absorption spectrum A spectrum in which absorption lines are prominent.

accretion Any process by which material is added to an astronomical body. This may, for example, occur during the formation of a protostar or during the transfer of matter in an interacting binary system.

accretion disc A disc of gas which forms around massive objects such as the accreting star in an interacting binary system. Material spirals inwards within the disc and falls onto the central object from the inner edge of the disc.

active regions Areas on the photosphere of the Sun where magnetic field lines are concentrated. These generate a number of different phenomena such as sunspots and flares.

angular momentum A measure of the momentum associated with rotation. The magnitude (L) of a body's angular momentum at any time is found by multiplying its moment of inertia by its angular speed at that time. The SI unit of angular momentum is the $\text{kg m}^2 \text{s}^{-1}$.

angular speed (ω) The rate at which an object (e.g. a wheel) turns, or at which a body (e.g. a satellite) orbits another body. Defined as the angle turned through in unit

time. The SI unit of angular speed is the radian per second (rad s^{-1}).

apparent visual magnitude A numerical measure of the apparent brightness of a body. For a star, it is determined by the flux density received in the V band, i.e. a band that approximates the response of human vision versus wavelength.

asteroseismology The study of stellar interiors from observations of global oscillations of their photospheres. Analogous to helioseismology but using only the combined light from the whole surface of a star.

astronomical unit (AU) The average distance from the Earth to the Sun. More precisely, the semimajor axis of the Earth's elliptical orbit around the Sun. (The size of the Earth's orbit varies slightly, so for precise work the informal definitions given above have been superseded by a more technical and exact definition.)

asymptotic giant branch (AGB) A region on the Hertzsprung–Russell diagram occupied by large cool stars after helium core burning has been completed. On the H–R diagram, stars of different masses approach this region from the left and evolve upwards so that the evolutionary tracks approach each other.

aurora A luminous atmospheric phenomenon observed in high latitudes. It is due to visible light emitted from atoms and molecules in the Earth's atmosphere that have been excited by collisions with electrons from the magnetosphere.

Balmer absorption lines A set of absorption lines due to photoexcitation of electronic transitions in hydrogen atoms, in which the electron makes a transition from a state corresponding to the energy level with $n = 2$, to a higher energy level.

baryon An elementary particle that comprises three quarks. Protons and neutrons are baryons.

big bang model The generally accepted scientific account of the evolution of the Universe from the earliest phases of its expansion. A feature of this model is that early in the history of the Universe, all matter was in a very hot and dense state, and the temperature of the matter dropped as time progressed.

binary star A system of two stars in orbit around each other.

bipolar outflow The phenomenon in which material ejected from a stellar system takes the form of two opposing jets. Some such jets appear to be associated with the early stages of stellar evolution.

black hole A region of space from which electromagnetic radiation and matter are unable to escape due to the action of gravity. Such regions are expected to be created by the catastrophic collapse of some massive stars.

black hole candidate An object believed, through its observed properties, to be a possible black hole.

black-body radiation curve *See* black-body spectrum.

black-body spectrum The spectrum of a black-body source (or ideal thermal source). This is a continuous spectrum with a characteristic shape, the peak wavelength depending on the temperature of the source, in accord with Wien's displacement law. A characteristic of sources that produce spectra that are close to the black-body form is that there is a degree of interaction between electromagnetic radiation and the material that makes up the source. (This leads to the formal definition of a black-body source as one which has the property that it absorbs perfectly any electromagnetic radiation that is incident on it and emits a black-body spectrum.)

blue-shift The decrease in the observed wavelength of radiation relative to the wavelength at which the radiation was emitted (the frequency is correspondingly increased). A common cause of blue-shift is the relative movement of the source towards the observer (an example of the Doppler effect).

Boltzmann constant The constant that relates kinetic energy and temperature in a gas (or pressure and temperature in a fixed volume and quantity of gas). It has the value $k = 1.38 \times 10^{-23} \text{ J K}^{-1}$.

bow shock The boundary of the Earth's magnetosphere where the solar wind is deflected. More generally it refers to any boundary between the flow of fast moving and stationary gas or plasma.

broadband spectrum A spectrum covering a wide range of wavelengths or frequencies, which represents the energy distribution of a source. It does not generally show narrow features such as absorption lines.

brown dwarf A stellar object of mass less than about $0.08M_{\odot}$, in which the core temperature is too low for hydrogen burning to be initiated.

carbon burning Nuclear fusion reactions in which two carbon nuclei fuse to form a heavier nucleus with a mass number of around 20 (e.g. sodium, neon or magnesium). Carbon burning occurs in massive post main sequence stars. The term is sometimes also used to refer to any nuclear fusion reaction where carbon is a reactant, for example when a carbon nucleus combines with a helium nucleus to produce an oxygen nucleus.

cataclysmic variable A form of interacting binary star in which material is transferred from a star which fills its Roche Lobe onto a white dwarf. They exhibit dramatic changes in luminosity that are most prominent in the optical, ultraviolet and X-ray parts of the spectrum.

centre of mass A point in a body, or amidst a set of bodies, that moves through space in the same way that the whole mass of the system would move were it concentrated at that point.

Cepheid A type of regular variable star, which pulsates with a period in the range from about a day to about 100 days. The changes in radius, temperature, and hence luminosity, arise from instabilities in the envelopes of such evolved giant or supergiant stars.

Chandrasekhar limit The theoretical upper limit to the mass of a white dwarf; about $1.4M_{\odot}$. Above this limit, electron degeneracy pressure cannot support the star and it collapses further.

chromosphere The region of the Sun just above the photosphere. It is the lowest layer of the Sun's atmosphere, characterized by a reddish hue, and by an increase of temperature with altitude through all but its lower reaches.

circumstellar disc A disc (or torus) of material surrounding a protostar. Possibly because of its rotational motion, it has not collapsed into the protostar.

circumstellar shell A shell of material, rich in molecules and dust, formed near a cool giant/supergiant from matter ejected by the star.

CNO cycle A cycle of nuclear reactions that convert hydrogen into helium using the elements carbon, nitrogen and oxygen as catalysts. This cycle predominates in upper main sequence stars.

cocoon nebula A compact, dense cloud of warm dust surrounding a protostar, which absorbs electromagnetic radiation from the hot protostar and re-radiates the energy in the infrared part of the spectrum.

collisional excitation A process that raises an ion, atom or molecule into a higher energy level when it collides with another particle.

colour index The difference, measured in magnitudes, of the brightness of an object in two specified wavebands (e.g. in the blue ‘B’ and visual ‘V’ wavebands of the UBV system, in which case the difference is denoted $m_B - m_V$ or simply $B - V$). It is a measure of the colour and hence the temperature of the object.

conduction A process of energy transfer in which atoms or molecules pass energy to their neighbours through collisions. In such a process energy is transferred from regions of relatively high temperature to regions of relatively low temperature.

conservation of angular momentum The principle that the angular momentum of a body, measured about any point, will not change provided no external force acts on that body. For an isolated system of several bodies, the total angular momentum, about any point, of the whole system will not change.

continuous spectrum A spectrum that is broad and smooth, i.e. the spectral flux density exhibits no sharp changes with wavelength.

convection A process of energy transfer in which a fluid in a gravitational field is heated from below to the point where the hotter, less dense fluid rises upwards, displacing the cooler, denser fluid downwards.

convection cells Localized regions of fluid flow set up by convection. A cell consists of a region where warm fluid is rising in a surrounding region where cool fluid is descending.

convection current A current of fluid in motion because of convection.

convective core The core of a star in which convection is the dominant process of energy transfer. For a star of mass greater than about $1.5M_{\odot}$, the temperature gradient in the core is sufficiently high to set up energy transfer by convection.

convective envelope The regions of a star outside the core in which convection is the dominant process of energy transfer. For a star of mass less than about $1.5M_{\odot}$, the core is non-convective but convection can take place further out in the form of a convective shell or envelope.

convective zone The region in the Sun (or in any other body) in which heat transfer is predominantly by convection.

core The central region of a body, distinguished on the basis of chemical composition, or physical properties (such as temperature), or physical processes (such as nuclear fusion).

corona The outer region of the Sun’s atmosphere; it is very extensive, has a very low density, and is extremely hot.

coronagraph An optical device that enables the Sun’s corona to be investigated. It blocks the far greater amounts of light that come from the photosphere, thus enabling the corona to be seen.

coronal hole Regions of the Sun’s corona where the solar magnetic field opens outward to interplanetary space rather than looping back on to the Sun. Such holes are thought to be a major source of the solar wind.

coronal loop Closed loops of magnetic field lines, extending from the Sun’s photosphere into the corona, which contain plasma at high temperature. They are typically observed through ultraviolet or X-ray emission from the hot plasma.

degeneracy A phenomenon described by quantum mechanics, where, at sufficiently low temperatures/high densities, certain particles (such as electrons or neutrons) are forced into higher energy levels because all the lower energy levels are fully occupied. Degeneracy gives rise to degeneracy pressure, which can support a star against gravitational collapse even if there is no nuclear burning to provide a gas pressure gradient.

dense clouds One of the coldest and densest components of the interstellar medium, rich in molecules. Dense clouds give birth to stars, mainly in the form of open clusters.

differential rotation The phenomenon whereby the rotation period of one part of a fluid body may differ from that of another. In the case of the Sun, for example, the rotation period varies with latitude and with depth.

diffuse cloud Interstellar clouds that have temperatures that are comparable to dense clouds, but which are much less dense, and not so rich in molecules.

dipole field The magnetic field produced by a dipole, such as a bar magnet, which has two poles, north and south.

dissociation The process of separation of two or more atoms in a molecule so that they are no longer bound together in the molecule.

Doppler effect The effect whereby the observed frequency of waves received from a source depends on the motion of the source relative to the observer. There is a corresponding change in the observed wavelength.

Doppler shift The change in wavelength (or frequency) at an observer's position, with respect to that emitted by the source, due to the motion of the source relative to the observer.

dwarf novae Cataclysmic variable stars that exhibit erratic outbursts in their optical emission of 2–5 magnitudes in a few days, followed by a slower decline to quiescent levels. The outbursts are not periodic, but recur over a timescale of weeks to months.

eccentricity A numerical measure of the extent to which an ellipse (such as an elliptical orbit) differs from a circle. It is half the distance between the two foci, divided by the semimajor axis.

eclipsing binary A binary star in which the plane of the orbit of the two components is sufficiently close to the observer's line of sight that one star can pass in front of (or behind) the other, causing a change in the perceived brightness of the binary system.

electric field The quantity, specified throughout some region of space, that determines the electric force that would act on a particle of given electric charge at any point within that region. At each point in the region the electric field possesses a strength and a direction, and these two quantities are given by the electric force per unit charge that would act at that point. The electric field in a region may be produced by electric charges, but is deemed to exist irrespective of whether there are any other electric charges present to 'feel' its effect.

electromagnetic radiation A form of radiation in which the transfer of energy from place to place may be attributed to the passage of wave-like disturbances in the electric and magnetic fields between those places (i.e. electromagnetic waves), or to the passage of photons from one place to the other. The wavelength or frequency of the waves (or the energy of the photons) may be used to assign particular kinds of electromagnetic radiation to specific parts of the electromagnetic spectrum, resulting in their classification as light, radio waves, X-rays, etc.

electromagnetic spectrum A collective term used to describe the various wavelength ranges of electromagnetic radiation. In order of increasing

wavelength, these ranges are gamma (γ) rays, X-rays, ultraviolet radiation, visible light, infrared radiation, microwaves and radio waves. *See also* spectrum.

electromagnetic wave model of light A model of visible light or any other form of electromagnetic radiation, in which the behaviour of light is described entirely in terms of electromagnetic waves. Some properties of electromagnetic radiation cannot be explained by this model. *See* quantum theory.

electromagnetic waves Fluctuating patterns of electric field and magnetic field in which the two fields are at right angles to each other and to the direction in which the waves travel. The speed at which they travel in a vacuum (to 3 significant figures) is $3.00 \times 10^8 \text{ m s}^{-1}$; this is the speed of light in a vacuum.

electron degeneracy pressure Pressure due to electron degeneracy. It occurs in the cores of red giants, and supports white dwarfs.

electronvolt (eV) A unit of energy often used for specifying the energy of photons or in energy-level diagrams. $1 \text{ eV} = 1.602 \times 10^{-19} \text{ J}$.

elliptical orbit The path followed by a celestial body, or spacecraft, in orbit about a more massive body (or of one object about the centre of mass of a binary system). In the absence of any perturbing forces, this path, or orbit, has the shape of an ellipse.

emission lines Narrow wavelength or frequency ranges in a spectrum where the spectral flux density is greater than at adjacent wavelengths (or frequencies).

emission spectrum A spectrum in which emission lines are prominent.

endothermic A term used to describe a process or reaction that requires a net input of energy for it to be sustained.

energy-level diagram A diagram showing the energies of the allowed states of a quantum physical system, such as an atom or a molecule, by virtue of the arrangement of its internal constituents. In the diagram energy is shown as increasing in the upward direction, and short horizontal lines are used to denote the energy levels themselves. The gaps between the levels indicate energies that cannot be attained by the system.

equations of stellar structure A set of equations describing the internal state of a star using parameters such as temperature, pressure, thermal conductivity.

equivalent width A measure of the strength of a spectral line. If a spectrum is plotted as spectral flux density against wavelength, it is the width of an area bounded by the spectral flux density of the continuum that has the same area as that between the actual spectral line and the continuum.

escape speed The minimum speed that enables a small body to just escape from the gravitational field of a far more massive body.

excited state Any state of a quantum physical system, such as an atom or molecule, that has a higher energy than the lowest energy state (ground state).

exothermic A term used to describe a process or reaction that produces a net output of energy as it progresses.

extinction The combined effect of the scattering of electromagnetic radiation by a medium, and absorption of such radiation by the medium.

extrasolar planet A planet orbiting a star other than the Sun.

extrinsic variables Variable stars that change in brightness as a result of some external effect rather than physical changes in the stars themselves. An example is an eclipsing binary.

faculae Bright patches on the solar photosphere generally associated with sunspots.

filament A long, winding dark feature, seen in visible light images of the Sun (particularly $H\alpha$ images), that is caused by huge clouds of relatively cool gas held high above the chromosphere by magnetic forces. Can also be seen as a prominence when at the limb of the Sun's disc.

flux density (F) A quantity describing the rate at which energy transferred by radiation is received from a source, per unit area facing the source. The SI unit of flux density is the W m^{-2} .

foci (singular focus) Two special points within an ellipse. In the case of an elliptical orbit of body A with respect to body B, body B lies at one focus, the other being empty.

fractional radius The distance from the centre of a spherical body, expressed as a fraction of the body's radius.

fragmentation The process by which a contracting interstellar cloud breaks up into a number of separate contracting cloudlets.

frequency The rate at which wavelengths of a wave pass a fixed point (i.e. the number per second passing the fixed point). The SI unit of frequency is the hertz (Hz), where $1 \text{ Hz} = 1 \text{ s}^{-1}$.

gamma-rays (γ -rays) Electromagnetic radiation with the highest frequencies, above the highest frequencies of X-rays. The photon energies are consequently also the highest.

geomagnetic disturbances Variations in the magnetic field at the surface of the Earth caused by motions of charged particles in the magnetosphere. In extreme cases these disturbances are known as geomagnetic storms.

geomagnetic storm Intense and rapid variations of the magnetic field at the surface of the Earth caused by motions of charged particles in the magnetosphere. These motions result from large coronal mass ejections striking the magnetosphere.

giant molecular cloud (GMC) complex A large type of cloud in the interstellar medium, consisting mainly of a mixture of diffuse clouds and dense clouds. They are probably the fundamental type of cloud structure in the interstellar medium.

giant star Any star that lies, on a Hertzsprung–Russell diagram, between the main sequence and the supergiants. Such stars are typically between about 5 and 25 times larger than the Sun.

global oscillations *See* helioseismology.

globular clusters Clusters of 10^5 to 10^6 very old stars tightly bound by gravity into a spherical region of space less than about 50 pc in diameter. They are found in a spherical distribution about the centre of our Galaxy and in other galaxies.

granules Bright, small patches on the Sun's photosphere that are the tops of rising columns of hot material. They form a seething pattern called solar granulation.

ground state The lowest energy state of an atom, a molecule or other quantum system.

$H\alpha$ absorption line An absorption line due to an electronic transition in hydrogen atoms, in which the atom absorbs a photon (photoexcitation), so that the electron makes a transition from a state corresponding to the electronic energy level with $n = 2$, to the one above, with $n = 3$. The photon wavelength (in a vacuum) is 656.3 nm: this is the longest wavelength Balmer absorption line.

H α image An image made using the emission line from hydrogen atoms corresponding to the reverse transition from that which gives rise to the H α absorption line.

Harvard Spectral Classification A classification of stellar spectra based on the relative strengths of the absorption lines. The main classes relate to photospheric temperature, and in order of descending temperature are O, B, A, F, G, K, M.

Hayashi track A track on the Hertzsprung–Russell diagram showing the theoretical evolution of a protostar as it approaches the main sequence.

heavy elements All chemical elements except the two that have the atoms with the lowest mass, i.e. all elements except hydrogen and helium.

heliopause The boundary between the region where the solar wind dominates the motion of plasma in the Solar System and beyond which lies the interstellar medium.

helioseismology The study of the solar interior based on the analysis of global oscillations of the Sun. Such oscillations can be studied because they cause observable effects at the photosphere.

heliosphere The volume of space within which the Sun, through the solar wind, influences its environment in the interstellar medium.

helium flash (core helium flash) An explosive release of energy in the core of a star that occurs after the star has left the main sequence and which initiates the process of helium burning (i.e. helium fusion) in the star. In order for helium ignition to take the form of what is, in effect, an internal explosion, the core must be degenerate at the time of ignition, and this implies that the star must be of relatively low mass, probably less than about 2.25 solar masses.

helium fusion The fusion of helium nuclei. Once the temperature in a star is sufficiently high, helium nuclei undergo fusion, via the triple alpha process, to produce carbon nuclei.

helium mass fraction (Y) A numerical measure of the proportion of helium in a sample of material, obtained by dividing the mass of helium in the sample by the total mass of the sample. In the Sun, $Y \approx 0.25$.

hertz (Hz) The SI unit of frequency: the rate at which wavelengths of a wave pass a fixed point (i.e. the number per second passing the fixed point).

Hertzsprung–Russell (H–R) diagram A diagram showing the luminosity and temperature of stars, which

is useful for comparing large numbers of stars and for tracking their evolution. Photospheric temperature is shown along the horizontal axis (increasing to the left), and luminosity is shown along the vertical axis. A star appears as a point on the diagram, corresponding to its current temperature and luminosity.

HII regions A hot, luminous component of the interstellar medium, comprising ionized hydrogen gas that is made visible by the presence of a hot, young star or stars. Strong ultraviolet radiation from hot stars ionizes the hydrogen, and the occasional recombination of an electron and proton to form a neutral hydrogen atom results in the emission of light, before the hydrogen is reionized.

horizontal branch A region on the Hertzsprung–Russell diagram occupied by stars of low mass and low metallicity after they have left the red giant branch during core helium burning. It is often seen in H–R diagrams of globular clusters, where many stars have similar luminosity but a wide range of surface temperatures, and hence lie in an approximately horizontal strip.

hot intercloud medium A component of the interstellar medium, characterized by a low density and a very high temperature. It is formed by material from within the cavities of supernova remnants.

hydrogen burning The conversion of hydrogen into helium through nuclear processes (hydrogen fusion).

hydrogen mass fraction (X) A numerical measure of the proportion of hydrogen in a sample of material, obtained by dividing the mass of hydrogen in the sample by the total mass of the sample. In the Sun, $X \approx 0.73$.

hydrostatic equilibrium The condition in which there is a balance between the inward force on a layer of a star (due to the gravitational attraction of material closer to the centre of the star) and the outward force on the layer (due to the difference in the pressure exerted on the layer by the layers above and below).

ideal gas A hypothetical gas that satisfies the ideal gas law. Real gases behave like ideal gases at sufficiently high temperatures and/or low densities.

ideal gas law The assertion that, for an ideal gas,

$$P = \frac{k\rho T}{m}$$

where P is pressure, k is the Boltzmann constant, ρ the density, T the absolute temperature, and m the average mass of the gas particles.

infrared radiation Electromagnetic radiation with frequencies or wavelengths between those of visible light and microwaves.

inner Lagrangian point The Lagrangian point in a binary system, between the two stars, at the centre of mass where the gravitational forces exerted by the two stars are equal in magnitude but act in opposite directions. This is where the two pear-shaped Roche lobes touch and it is through this point that mass transfer in an interacting binary system takes place.

instability strip A roughly vertical region on the Hertzsprung–Russell diagram where the structure of stars is unstable. Any star in this region (e.g. a Cepheid) pulsates and therefore shows variability.

interstellar cirrus Widespread wisps of cool interstellar matter, possibly the result of circumstellar shells as they spread out and become cooler and more diffuse.

interstellar medium (ISM) The thinly distributed matter that fills interstellar space in the Galaxy. It consists of gas (mainly hydrogen), with a trace of dust, and is made up of several different components, such as dense clouds, HII regions and the intercloud medium.

interstellar reddening The effect whereby the observed colour of a star is influenced by the presence of dust in the interstellar medium. The size of the dust grains results in more efficient absorption and scattering of short wavelength (blue) light than of longer wavelength (red) light, so as light from a star encounters more and more dust, the apparent colour of the star becomes progressively redder.

intrinsic variables Variable stars that change in brightness as a result of a change in the properties of the stars themselves. An example is a pulsating variable.

ionization energy The energy required to remove an electron from an atom in its ground state.

iron group Elements with relative atomic masses around $A \sim 56$, such as iron, chromium, manganese, cobalt and nickel, which have the lowest rest energy per nucleon.

irregular variable A star whose luminosity varies with time in an irregular manner. The timescale is *very* short compared with the stellar lifetime.

Jeans mass The critical mass that a uniform, spherical, non-rotating cloud must have before it will collapse under its own gravitational attraction.

kinetic energy The energy that a body has by virtue of its motion.

Lagrangian point One of the five points in a binary system at which a small body can maintain a stable orbit about the system's centre of mass. Viewed from a frame of reference rotating with the binary system, a small body placed at any one of these points feels no net force.

light curve A diagram showing the variation of brightness (e.g. magnitude, flux density or luminosity) with time, for a celestial object such as a variable star or supernova.

light-year (ly) The distance travelled by light (or any other form of electromagnetic radiation) through a vacuum in one year. $1 \text{ ly} \approx 9.46 \times 10^{15} \text{ m}$.

limb darkening The phenomenon whereby the extremities of the image of a spherical body are darker than the central regions. In the case of the Sun it arises in visible light images because towards the solar limb we are seeing less deeply into the photosphere, our view being confined to the outer and hence cooler and dimmer part of the photosphere.

line spectra Spectra which exhibit narrow lines due to absorption (absorption lines) or emission (emission lines) of electromagnetic radiation (called, respectively, absorption spectra and emission spectra).

local thermodynamic equilibrium The condition in which the matter in any appropriately localized region within a body may be characterized by a local temperature, and the radiation coming from any such region is in equilibrium with (i.e. has the same local temperature as) the matter in that region. The assumption of local thermodynamic equilibrium is useful in models of stellar envelopes and atmospheres.

lower main sequence star A star with a mass of less than about $1.5M_{\odot}$, occupying the lower part of the main sequence on the Hertzsprung–Russell diagram. In such stars the pp-chain dominates the production of energy.

luminosity The rate at which energy is carried away from a star by electromagnetic radiation. The SI unit of luminosity is the watt (W), where $1 \text{ W} = 1 \text{ J s}^{-1}$.

luminosity class One of a number of classes of stars (determined by means of certain spectral features such as the widths of particular absorption lines) that typically contains stars with a wide range of spectral classes but a rather narrow range of sizes. Amongst the commonly used luminosity classes are Class Ia (highly luminous supergiants), Class III (giants) and Class V (main sequence stars). Each luminosity class can be represented by a line on the Hertzsprung–Russell

diagram, with the consequence that specifying both the spectral class and the luminosity class of a star (as in G2 V, for the Sun) permits the luminosity of the star to be approximately determined.

magnetic field The quantity, specified throughout some region of space, that determines the magnetic force that would act on a particle of given electric charge moving with given velocity through any point within that region. At each point in the region, the magnetic field possesses a strength and a direction. The magnetic field in a region may be produced by magnets or by moving charged particles (e.g. electric currents), but is deemed to exist irrespective of whether there are any other moving charged particles or magnets present to ‘feel’ its effect.

magnetic field line An imaginary directed line (i.e. a line with an arrow head on it) passing through the region occupied by a magnetic field in such a way that it has the same direction as the magnetic field at every point. In diagrams, it is conventional to draw magnetic field lines in such a way that their density (i.e. the number of lines per unit area) indicates the relative strength of the magnetic field. *See* polarity.

magnetic reconnection A process taking place in a plasma, in which neighbouring, oppositely directed, magnetic field lines suddenly part and reconnect in a new configuration. The abrupt change in the magnetic field represented by this process can release large amounts of energy and is thought to be important in explaining solar flares and other phenomena.

magnetogram A map of the magnetic field strength over a surface (usually of the Sun).

magnetograph An instrument which maps the magnetic field strength in the Sun’s photosphere by measuring the splitting of certain spectral lines due to the local magnetic field.

magnetosphere The region around the Earth (or another planet) where its magnetic field influences the motion of charged particles.

main sequence The region on the Hertzsprung–Russell diagram where stars spend most of their lives. Most of the observed stars lie on the main sequence where they are powered by hydrogen burning in their cores.

main sequence turn-off The point on the main sequence of the Hertzsprung–Russell diagram of a star cluster above which no stars are present. It corresponds to stars that are just reaching the end of their time on the main sequence, and is therefore an indication of the age of the cluster.

mass–luminosity relationship A relationship between the mass of a main sequence star and its luminosity. It shows a dramatic increase in luminosity with increasing mass.

medium Any material (solid, liquid or gas) through which particles or radiation may pass.

metallicity (Z) A numerical measure of the proportion of heavy elements in a sample of material, obtained by dividing the mass of heavy elements in the sample by the total mass of the sample. In the Sun, $Z \approx 0.02$.

microwaves Electromagnetic radiation with frequencies or wavelengths between those of infrared radiation and radio waves.

Mira variable A type of variable star. Mira variables are giant stars in a late stage of evolution (on the asymptotic giant branch) which exhibit long period (100–1000 days) global pulsations. The periods and amplitudes are subject to variations from cycle to cycle. Mira variables are named after the star Mira (omicron Ceti).

moment of inertia (I) A quantity, expressed relative to a specified axis, that measures the distribution of a system’s mass with respect to that axis. The moment of inertia of a rigid body plays an important part in determining how that body will rotate about the specified axis under given conditions. Broadly speaking, the same mass, more widely distributed, has a larger moment of inertia about a specified axis. The SI unit of moment of inertia is the kg m^2 .

neon burning A nuclear fusion reaction in which neon nuclei react with helium nuclei (α -particles) to form magnesium. The helium nuclei are themselves formed from the photodisintegration of neon.

neutrino A type of elementary particle that is electrically neutral and has very low mass. Neutrinos generally travel at speeds very close to the speed of light in a vacuum, and interact with other particles extremely weakly. There are three sub-types: electron, muon and tauon neutrinos.

neutron degeneracy pressure Pressure that arises from neutron degeneracy. It supports neutron stars.

neutron star A star of mass between around 1.4 and 3 to $5M_{\odot}$ with a radius of about 10 km, formed from the collapsed core of a supergiant, and made of material exceptionally rich in neutrons. Most known neutron stars are observed as pulsars.

non-thermal source A source of electromagnetic radiation that emits for reasons other than those relating to its temperature.

nova An outburst in which a star increases its brightness by a factor of about 10^3 in a few days, and then slowly returns to its original brightness. Novae are now associated with stars in certain types of close binary system, where the nova outburst is a consequence of mass being transferred from one star to the other.

OB association A group of young stars containing several stars of spectral type O and B in the Harvard Spectral Classification.

open cluster A cluster of up to a few hundred stars, formed from a cloulet that has fragmented from a larger dense cloud. The stars are only loosely bound together in an open structure.

oxygen burning A nuclear fusion reaction, occurring in massive post main sequence stars, in which two oxygen nuclei fuse to form silicon and helium nuclei.

parallactic ellipse The apparent elliptical movement of a nearby star in the plane of the sky relative to distant stars during the course of a year due to parallax.

parallax The quantity that describes the change in direction to a celestial body (relative to a background of far more distant bodies) resulting from a given change in position of the observer perpendicular to the direction of the body. The term parallax is often used to refer specifically to stellar parallax, p , when the change in position of the observer is one astronomical unit. This quantity is important in the determination of the distance of nearby stars.

parsec (pc) The distance to a celestial body that has a stellar parallax of one arc second. $1 \text{ pc} = 3.09 \times 10^{16} \text{ m}$.

period–luminosity relationship A correlation between period and luminosity; in particular the relationship between period and luminosity of Cepheid variables that enables these stars to be used as standard candles. (Absolute visual magnitude, M_V , is generally used in place of luminosity when using this relationship.)

photodisintegration The process in which a nucleus is split apart by the absorption of a gamma-ray photon. This type of reaction plays an important role in the later stages of stellar nucleosynthesis.

photoemission The process in which a photon is emitted by an atom or molecule.

photoevaporation The process in which an interstellar cloud is eroded by the action of intense ultraviolet radiation from nearby highly luminous stars. The ultraviolet dissociates the hydrogen molecules (H_2) in the cloud into individual hydrogen atoms.

photoexcitation The process in which an atom or molecule is excited by the absorption of a photon.

photometric method A method of determining stellar photospheric temperatures (or the surface temperature of other bodies) by comparing the amount of radiation emitted over at least two different wavelength regions.

photon The particle of electromagnetic radiation in the photon model of light. The photon energy ε is proportional to the frequency f of the associated radiation; $\varepsilon = hf$ where h is the Planck constant.

photon model of light A model in which a ray of visible light, or of any other form of electromagnetic radiation, is treated as a stream of separate particles called photons.

photosphere The ‘surface’ of the Sun, or of any other star – the thin layer from which comes nearly all of the solar (or stellar) radiation that we observe.

plages Extensive bright regions of the solar chromosphere, seen particularly well in $\text{H}\alpha$ images. They often occur directly above active regions of the photosphere that contain sunspots.

Planck constant (h) The constant that relates the energy ε of a photon to the frequency f of the wave with which it is associated: $\varepsilon = hf$.

Planck curve *See* black-body spectrum.

planetary nebula A shell of material ejected towards the end of its life by a star whose initial mass was less than about $11M_\odot$. The hot central star of the planetary nebula becomes a white dwarf.

plasma A fluid in which there is a high degree of ionization.

polarity The property of the pole of a magnet, or of any other region from which magnetic field lines emanate, that determines the direction of those magnetic field lines. By convention, magnetic field lines are directed away from north magnetic poles (regions of positive polarity) and towards south magnetic poles (regions of negative polarity).

positron (e^+) A kind of positively charged elementary particle which has the same mass, magnitude of charge, and many other properties as an electron.

ppI chain (or cycle) A sequence of nuclear reactions that is responsible for the bulk of the Sun's radiant energy, and that of comparable or lower mass stars. The net effect of the chain is the conversion of four hydrogen nuclei (protons) into one helium nucleus – an example of nuclear fusion.

ppII and ppIII chains Two sequences of nuclear reactions that predominate in the more massive lower main sequence stars. The net effect of each chain is the conversion of four hydrogen nuclei (protons) into one helium nucleus.

pressure broadening The broadening of a spectral line due to the high density of material in certain stellar atmospheres. This in turn is due to the modification of the energy levels of an atom that result from the close proximity of other atoms.

primordial nucleosynthesis The nuclear processes occurring during the first few minutes of the expansion of the Universe that were responsible for forming nuclei of the light elements (such as helium and lithium).

prominence A kind of bright filamentary feature seen beyond the solar limb. Prominences are huge clouds of relatively cool gas held high above the chromosphere by magnetic fields. Also seen as filaments.

proper motion The quantity that describes the angular movement of a star in the plane of the sky, normally expressed in arc seconds per year.

protostar A term used to describe a star during the earliest stage of its life, during which it is gravitationally contracting and before nuclear fusion has been initiated.

pulsar A widely used abbreviation for a pulsating radio star. Pulsars are widely believed to be rapidly rotating neutron stars with strong magnetic fields, which emit beams of radio waves from the vicinity of their two magnetic poles.

pulsating variable A type of intrinsic variable star that changes in luminosity, radius and temperature in a cyclic manner.

quantum theory A wide-ranging theory that describes, amongst other things, the structure and behaviour of atoms and their interaction with electromagnetic radiation. It accounts for the phenomena that are embraced by the photon model of light, and implies the existence of energy levels in atoms.

quark star A hypothetical type of star, even more dense than a neutron star, in which the neutrons lose their individual identities and matter exists as a sea of quarks.

radial velocity The component of a star's velocity in the line of sight of an observer, i.e. in a radial direction towards or away from the observer.

radiation A process of energy transfer in which energy is transported from place to place by the passage of waves or the direct movement of subatomic particles. The term radiation is also used to describe the travelling disturbances responsible for the energy transfer.

radiation pressure A pressure exerted by photons on any object that absorbs or scatters them. Although it is a weak force it is significant for individual atoms and molecules as well as small dust grains.

radiative zone The region in the Sun (or in any other body) in which energy transfer is predominantly by electromagnetic radiation.

radio waves Electromagnetic radiation with the lowest frequencies/longest wavelengths, extending from the lowest frequency/longest wavelength microwaves.

random walk A process in which a particle (such as a photon) encounters other particles, and has an almost equal chance of travelling in any direction after each encounter.

recombination The process in which an electron and an ion combine, i.e. the opposite of ionization. The electron is typically captured into a high-energy orbit and then cascades downward through the atom's energy levels emitting photons as it does so.

red giant branch (RGB) A region on the Hertzsprung–Russell diagram occupied by stars after they leave the main sequence and are undergoing shell hydrogen burning.

red giant A large star with photospheric temperature less than about 6000 K. Main sequence stars with masses of less than about $11M_{\odot}$ evolve to become red giants.

red-shift The increase in the observed wavelength of radiation relative to the wavelength at which the radiation was emitted (the frequency is correspondingly decreased). A common cause of red-shift is the relative movement of the source away from the observer (an example of the Doppler effect).

regular variable A star whose luminosity varies with time in a regular manner, on a timescale that is very short compared with the star's lifetime (e.g. a Cepheid).

relative spectral flux density The spectral flux density expressed as a fraction of some arbitrarily chosen reference value.

rest energy The energy E of a particle at rest, given by Einstein's equation $E = mc^2$, where m is the mass of the particle, and c is the speed of light in a vacuum.

Roche lobe The pear-shaped surface around one star in a binary star system, inside which the gravitational force of that star dominates. It represents the maximum volume that the star may occupy before it begins to lose mass through the inner Lagrangian point to its companion. Both stars are surrounded by Roche lobes, and in cross-section the surface has a figure-of-eight shape.

Roche lobe overflow The process whereby matter is transferred from one star to another in an interacting binary system. The transfer occurs when the donating star fills its Roche lobe, and takes place through the inner Lagrangian point.

rotational transition A transition in a molecule between two states corresponding to different amounts of molecular rotational energy.

r-process reactions Nuclear reactions that form elements heavier than iron by the rapid absorption of several neutrons. The reactions are thought to occur for a few seconds during supernovae, and are particularly important for building elements from the unstable (radioactive) isotopes that are formed in supernovae.

Russell–Vogt theorem A theorem stating that a certain mass of stellar material of fixed composition can reach only one stable configuration. This stable configuration corresponds to one point on the Hertzsprung–Russell diagram.

scattering The process in which photons bounce off particles in random directions.

Schwarzschild radius (R_S) The radial distance from the centre of a black hole at which the escape speed equals the speed of light. Given by

$$R_S = \frac{2GM}{c^2}$$

where G is the universal gravitational constant, M is the mass of the black hole, and c is the speed of light in a vacuum.

second law of thermodynamics A law that (among other things) states that heat spontaneously flows from a hotter body to a cooler body but is not spontaneously transferred from a cooler body to a hotter body.

semimajor axis A distance equal to half the longest axis of an ellipse.

shell helium flashes Approximately periodic, explosive releases of energy occurring within the helium-burning shell of material in asymptotic giant branch stars.

shock front The very thin transition zone between an unperturbed medium and a shell of material moving very rapidly through the medium.

sidereal period The period of one revolution of a body in orbit about another, or of one rotation of a body about its own axis, measured relative to the stars.

silicon burning A set of nuclear reactions that involve the fusion of helium nuclei (α -particles) with silicon and the heavier nuclei that are subsequently formed. The α -particles are formed by photodisintegration reactions. Such a process is exothermic up until the point at which elements in the iron group are formed.

SN 1987A The first relatively nearby, unobscured supernova in modern times, occurring about 163 000 light-years away, in the Large Magellanic Cloud, a nearby galaxy. The first radiation from the supernova reached the Earth on 24 February 1987.

solar activity Activity in the Sun, as displayed by a number of phenomena, including sunspots, plages, filaments, prominences and solar flares, all of which are more prevalent at times of higher activity. At such times the corona exhibits streamers jutting out in all directions.

solar activity cycle A roughly 11-year cycle in the level of solar activity (some associated magnetic phenomena have a 22-year cycle).

solar cycle *See* solar activity cycle.

solar flare An energetic event, in which solar radiation at radio, X-ray and other wavelengths increases markedly and suddenly.

solar granulation The pattern of granules on the Sun's photosphere.

solar interior The vast bulk of the Sun that is beyond direct observation, i.e. below the photosphere.

solar limb The edge of the circular disc that the Sun exhibits to an observer.

solar luminosity The rate at which energy is transported away from the Sun by electromagnetic radiation, $L_{\odot} \approx 3.84 \times 10^{26} \text{ J s}^{-1}$.

solar models Mathematical models that describe the physical conditions of the solar interior.

solar neutrino problem The apparent discrepancy between the numbers of solar neutrinos measured by detectors on the Earth and those predicted by solar models. This discrepancy has now been explained by the fact that some neutrinos appear to change type between their emission and detection.

solar neutrinos Neutrinos originating in nuclear reactions in the Sun. They provide a direct test of our ideas about solar nuclear reactions.

solar rotation The rotation of the Sun on its axis. The intrinsic (sidereal) period, measured at the photosphere, exhibits differential rotation, varying from about 25 days at the solar equator to about 36 days near the poles.

solar wind A gusty stream of high-speed particles (mainly protons and electrons) that spreads out from the Sun, carrying traces of the Sun's magnetic field with it.

space velocity The velocity of a star through space relative to the Sun. Its components are radial velocity and transverse velocity.

space weather A collective term for the range of effects of solar activity on the Earth's environment.

spectral flux density (F_{λ}) The quantity that describes the rate at which energy transferred by radiation is received from a source, per unit area facing the source, per unit wavelength range.

spectrometric method A method of determining the photospheric temperature of a star, and its luminosity, by examining the absorption lines in its spectrum.

spectroscopic binaries Binary stars which are identified as such from the Doppler shifts of their spectral lines. Spectroscopic binaries may show two sets of spectral lines that exhibit relative motion as the two stars orbit their common centre of mass or, if one of the stars is very faint, there may be just a single set of observable lines that change their wavelength (or frequency) periodically.

spectroscopic parallax A method for obtaining (approximate) stellar distances based on an observation of a star's flux density and a spectroscopic determination of its approximate luminosity. *See also* luminosity class.

spectroscopy The study of spectra and spectral lines.

spectrum (plural spectra) A representation (usually as a visual image or a graph) of the way in which the strength or intensity of radiation emitted or received from a specified source is distributed with respect to wavelength or frequency.

speed of light in a vacuum (c) The speed at which electromagnetic radiation travels through a vacuum, which, to 3 significant figures, is $3.00 \times 10^8 \text{ m s}^{-1}$.

spiral density wave A long-lived, self-consistent pattern of density enhancement that may arise in a disc of stars and gas, thought possibly to account for the pattern of star formation that gives rise to spiral arms in spiral galaxies.

s-process reactions A series of nuclear reactions initiated by the slow absorption of neutrons.

stability The property of a system that enables it to return to its original position or configuration following some (usually small) disturbance or perturbation. In the case of a star, the term stability is often used to refer to the star's ability to counteract any tendency for it to expand or contract. The main sequence lifetime of a star represents an extended demonstration of its stability.

standard candle Any type of object whose luminosity is known from its observable properties, thus allowing its distance to be inferred from the difference between its apparent brightness and its true brightness.

star cluster Any group of stars with more than a few members, in a relatively small volume of space.

Stefan–Boltzmann constant (σ) The constant that relates the power I radiated by unit area of a black-body source to its absolute temperature T , i.e. $I = \sigma T^4$.

stellar parallax The quantity that describes the change in the direction to a celestial body against a background of far more distant bodies, resulting from a change of one astronomical unit in the observer's position, in a direction perpendicular to the direction to the body.

stellar wind The outflow of material from the surface of a star.

stellar wind accretion A mass transfer process in a binary star system in which some of the strong stellar wind from one star is captured by its companion.

strong shock The effect on a medium of being subjected to the passage of a high-speed flow. The material in the medium is compressed and its temperature

raised in the transition zone, called the shock front, between the flow and the unperturbed region. The material is said to have undergone a ‘strong shock’ or be ‘shocked’.

subgiant Any star in the zone of the Hertzsprung–Russell diagram that is between the main sequence and the red giant branch. Most subgiants are on the way to becoming red giants.

sunspots Relatively cool, small patches on the Sun’s photosphere. In visible light images they appear as dark patches.

supergiant A star that lies along the top of the Hertzsprung–Russell diagram, i.e. a star with the greatest luminosity. Main sequence stars with masses greater than about $11M_{\odot}$ evolve to become supergiants. Later, such stars become Type II supernovae.

supergranulation A large-scale pattern of upward and downward motion of the Sun’s photosphere, possibly resulting from a deep layer of large convection cells.

supernova An outburst in which a star suddenly increases in brightness by an enormous factor ($\sim 10^6$). Such a star is ending its life in a gigantic explosion resulting from the collapse of its core.

synchrotron radiation Electromagnetic radiation with a continuous spectrum, emitted by electrically charged particles, usually electrons, as they pass through magnetic fields. For appreciable radiation to be emitted, the particles must have very high energies.

T Tauri star A type of irregular variable that exhibits variations in luminosity by factors of two or three over intervals of the order of a few days. They are thought to be very young stars, losing mass before settling on to the main sequence.

termination shock The region in the heliosphere where the solar wind begins to slow down due to the pressure of the interstellar medium.

thermal pulse A rapid release of energy, lasting perhaps a few hundred years, typically caused by a shell helium flash in a star. Thermal pulses are thought to occur almost periodically within stars that have reached an appropriate stage in their evolution, with individual pulses being separated by 10^4 to 10^5 years.

thermal source A source that emits electromagnetic radiation because of its temperature (the higher the temperature, the greater the amount of radiation emitted per unit area of the source).

thermalization The process through which a distribution of photon energies is converted into a black-body spectrum as a result of multiple scattering.

total eclipse of the Sun The natural phenomenon that occurs when the Moon passes between the Earth and the Sun, completely blocking the photosphere from the view of appropriately positioned observers on the Earth’s surface.

transition region A thin layer in the Sun’s atmosphere, between the chromosphere and the corona.

transverse velocity The component of a star’s velocity in the plane of the sky, i.e. in a direction perpendicular to the line of sight of an observer.

trigger mechanism An event or process that initiates some further series of events. In astronomy, it often refers to an event or process that compresses an interstellar cloud and initiates star formation.

trigonometric parallax A method of determining the distances of celestial bodies based on measurements of the parallax of those bodies. *See* parallax.

triple alpha (3α) process The nuclear fusion reactions in which three helium nuclei (alpha particles) combine to form one carbon nucleus. It is the dominant nuclear process in the core of a red giant.

Type II supernova A particular kind of supernova that marks the explosive conclusion of the supergiant phase of the life of stars with masses greater than about $11M_{\odot}$.

UBV system A set of wavelength ranges commonly used in observations of stars. The wavebands are: U, ultraviolet, central wavelength 360 nm; B, blue, 440 nm; V, visual, 550 nm.

ultraviolet radiation Electromagnetic radiation with frequencies or wavelengths between those of X-rays and visible light.

upper main sequence star A star with a mass greater than about $1.5M_{\odot}$, occupying the upper part of the main sequence on the Hertzsprung–Russell diagram and in which the CNO cycle dominates the production of energy.

variable star A star whose luminosity varies on a timescale (seconds to years) that is very short compared with the star’s lifetime. Variable stars are subdivided into irregular variables and regular variables.

vibrational transition A transition in a molecule between two states corresponding to different amounts of molecular vibrational energy.

visible light Electromagnetic radiation with frequencies or wavelengths between those of ultraviolet radiation and infrared radiation. Our eyes are sensitive to visible light.

visual binary system A binary star in which both stars can be observed as distinct points of light.

warm intercloud medium A low-density component of the interstellar medium characterized by a moderately high temperature; probably derived largely from interstellar clouds, by ‘evaporation’.

wavelength The distance over which a periodic wave repeats itself, e.g. the distance from one peak of the wave to the next.

white dwarf The remnant left over when a star sheds a planetary nebula. They lie below the main sequence in the Hertzsprung–Russell diagram.

white light image An image of an object formed using the whole range of visible light wavelengths.

Wien’s displacement law A law that, for a black-body source, relates the wavelength λ_{peak} at which the relative spectral flux density is a maximum, to the absolute temperature T of the source. In SI units $(\lambda_{\text{peak}}/\text{m}) = (2.90 \times 10^{-3})/(T/\text{K})$. It is also known as Wien’s law.

Wolf–Rayet star A rare type of hot, massive star which exhibits high mass loss and emission lines, indicating that the outer layers have been ejected and the core revealed.

X-rays Electromagnetic radiation with frequencies or wavelengths between those of gamma-rays and ultraviolet radiation.

X-ray binary An interacting binary system that emits X-rays during the process of accretion. X-ray binaries contain a white dwarf, a neutron star or a black hole and dominate the sky at X-ray wavelengths

X-ray pulsar A neutron star in an accreting binary system which shows regular pulses in its X-ray emission. The origin of the X-ray pulsations is linked to the interaction between the accreting material and the magnetic field of the neutron star.